

WASTE TO ENERGY WORKSHOP BACKGROUND DOCUMENT

Workshop Purpose: *To inform government officials of the potential of DoD waste to energy systems and to launch working groups which will advance the growth of the field.*

30,000 Foot Level View

- Waste to Energy: The Need and Opportunity
- Waste Characterization
- Waste to Energy Technologies
- Waste to Energy Case Studies

INTRODUCTION

This document is intended to help prepare invitees to the Waste to Energy (WTE) Workshop for participation in a waste to energy discussion. In preparing for the workshop, it is necessary to first define what is meant by “waste to energy” and to narrow the focus of what will be discussed during the two day workshop. Waste to energy definitions, requirements for the production and use of “renewable energy” on federal installations, waste characterization/availability and waste conversion technologies will be addressed. This document is only a starting point from which to initiate discussion. It is anticipated that this workshop will be the first of many for government stakeholders to share information and to develop a targeted approach to pursue waste to energy opportunities both on installations and deployed.

WASTE DEFINED

What is meant when the term “waste to energy” is used? The term has many different meanings to different people. Typically, waste is defined as garbage/refuse, something that no longer has use or value. For the purposes of this document and the workshop, the term “waste to energy” will be defined within the context of U.S. federal energy and environmental policy. As such, the definitions below may challenge the typical definition of “waste” and define it in such a way that “waste” may in fact begin to have “use” or “value” when considered from an energy recovery perspective.

The Energy Policy Act of 2005 (EPACT 2005) and Executive Order 13423 (E.O. 13423) both identify “biomass, landfill gas and or municipal solid waste” as renewable energy sources.

However, the term “energy” is defined differently between the two documents. Within EPACT 2005 “renewable energy” is limited to “electrical” energy, whereas, in E.O. 13423, “renewable energy” includes both electrical and thermal.

DEFINITIONS

EPACT 2005

Renewable Energy- electric energy generated from solar, wind, **biomass, landfill gas**, ocean (including tidal, wave, current, and thermal), geothermal, **municipal solid waste**, or new hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project.

Biomass- Any lignin waste material that is segregated from other waste materials and is determined to be nonhazardous by the Administrator of the Environmental Protection Agency and any solid, nonhazardous, cellulosic material that is derived from--

- (A) any of the following forest-related resources: mill residues, precommercial thinnings, slash, and brush, or nonmerchantable material;
- (B) solid wood waste materials, including waste pallets, crates, dunnage, manufacturing and construction wood wastes (other than pressure-treated, chemically-treated, or painted wood wastes), and landscape or right-of-way tree trimmings, but not including municipal solid waste (garbage), gas derived from the biodegradation of solid waste, or paper that is commonly recycled;
- (C) agriculture wastes, including orchard tree crops, vineyard, grain, legumes, sugar, and other crop by-products or residues, and livestock waste nutrients; or
- (D) a plant that is grown exclusively as a fuel for the production of electricity.

Executive Order 13423

Renewable Energy-electric energy from all renewable energy sources that satisfy the definitions and qualifications in EPACT 2005 **and qualified non-electric energy** from new renewable energy sources of the types detailed in EPACT 2005. Examples include but are not limited to thermal energy from solar ventilation pre-heat systems, solar heating and cooling systems...biomass heating and thermal uses of geothermal and ocean resources.¹

Energy Information Administration (EIA)

Renewable Energy- “Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Note that this definition defines renewable energy according to its primary source, which

¹ U.S. Department of Energy, Energy Efficiency and Renewable Energy, Federal Energy Management, 28 January 2008. The 2007 Federal Energy Management (FEMP) Renewable Energy Requirement Guidance for EPACT 2005 and Executive Order 13423 Final. 30 April 2008. <http://www1.eere.energy.gov/femp/pdfs/epact05_fedrenewenergyguid.pdf>.

contrasts with other definitions that define any recurring waste stream as renewable.” Applying this definition, the EIA has begun to divide **municipal solid waste into biogenic versus non-biogenic waste**.²

Biomass Waste- Defined by the Energy Information Administration as organic non-fossil material of biological origin that is a byproduct or a discarded product. **“Biomass waste” includes municipal solid waste from biogenic sources, landfill gas, sludge waste, agricultural crop byproducts, straw, and other biomass solids, liquids, and gases;** but excludes wood and wood-derived fuels (including black liquor), biofuels feedstock, biodiesel, and fuel ethanol. **Note:** EIA “biomass waste” data also include energy crops grown specifically for energy production, which would not normally constitute waste.³

DEPARTMENT OF ENERGY

Municipal Solid Waste (MSW)

Waste material from households and businesses in a community that is not regulated as hazardous.

Municipal Waste

As defined in the Energy Security Act (P.L. 96-294; 1980) as "any organic matter, including sewage, sewage sludge, and industrial or commercial waste, and mixtures of such matter and inorganic refuse from any publicly or privately operated municipal waste collection or similar disposal system, or from similar waste flows (other than such flows which constitute agricultural wastes or residues, or wood wastes or residues from wood harvesting activities or production of forest products)."

Municipal Waste to Energy Project (or Plant)

A facility that produces fuel or energy from municipal solid waste.⁴

REQUIREMENTS

EPACT 2005

- The President, acting through the Secretary of Energy, shall seek to ensure that, to the extent economically feasible and technically practicable, of the total amount of electric energy the Federal government consumes during any fiscal year, the following amounts shall be renewable energy:

² Energy Information Administration. Methodology for Allocating Municipal Solid Waste to Biogenic/Non-Biogenic Energy Municipal Solid Waste Report. 30 April 2008.
<http://www.eia.doe.gov/cneaf/solar/renewables/page/mswaste/msw_report.html>.

³ Energy Information Administration. Glossary. 30 April 2008 <http://www.eia.doe.gov/glossary/glossary_b.htm>.

⁴ U.S. Department of Energy, Energy Efficiency and Renewable Energy. Glossary of Energy-Related Terms. 30 April 2008.
<http://www.eere.energy.gov/consumer/information_resources/index.cfm/mytopic=60001#M>.

- Not less than 3 percent in fiscal years 2007 through 2009
- Not less than 5 percent in fiscal years 2010 through 2012
- Not less than 7.5 percent in fiscal year 2013 and each fiscal year thereafter

E.O. 13423

- Ensure that at least half of the statutorily required renewable energy consumed by the agency in a fiscal year comes from new renewable sources and to the extent feasible, the agency implements renewable energy generation projects on agency property for agency use.
- Ensure that the agency reduces the quantity of toxic and hazardous chemicals and materials acquired, used, or disposed of by the agency, increases diversion of solid waste as appropriate and maintains cost effective waste prevention and recycling programs in its facilities.⁵

WHY WASTE TO ENERGY?

The increased focus on energy is primarily driven by an overarching need to

- reduce U.S. dependence on fossil fuels;
- significantly reduce the production of greenhouse gas emissions; and
- ensure energy security

In response, the Energy Policy Act of 2005 and Executive Order 13423 directed federal agencies to reduce energy consumption, reduce petroleum fuels and increase the use of clean, alternative fuels and to increase the amount of renewable energy consumed and encourage the on-site production of renewable energy.

Waste to energy, offers an opportunity for federal agencies to meet their renewable energy goals while also addressing the environmental and economic issues of waste disposal.

The production and use of renewable energy from “waste” is one approach that can assist in attaining federal energy goals. Renewable Energy, as defined in EPACT 2005 and E.O. 13423 includes energy from **biomass**, **landfill gas** and **municipal solid waste**.

In addition to energy requirements, Executive Order 13423 also directs federal agencies to

- use of sustainable environmental practices, including acquisition of bio-based, environmentally preferable, energy efficient, water efficient and recycled content products ;
- increase the diversion of solid waste; and
- maintain cost effective waste prevention and recycling programs in facilities

⁵ U.S. Department of Energy, *Energy Efficiency and Renewable Energy, Federal Energy Management*, 28 January 2008. 2007 Federal Energy Management (FEMP) Renewable Energy Requirement Guidance for EPACT 2005 and Executive Order 13423 Final. 30 April 2008. <http://www1.eere.energy.gov/femp/pdfs/epact05_fedrenewenergyguid.pdf>.

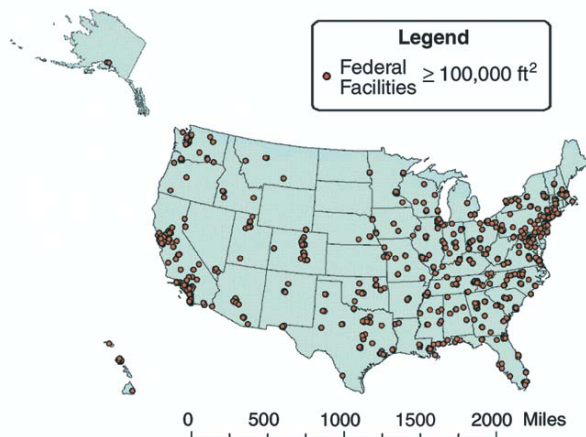
Waste to energy connects the two requirements (renewable energy production/consumption and waste diversion) and ensures an opportunity to meet both.

DoD Waste Resources

According to the Fiscal Year 2007 Defense Environmental Program Annual Report to Congress, DoD generated 5.8 million tons of solid waste (3.4 million tons of Construction and Demolition debris and 2.5 million tons of non-hazardous municipal solid waste). DoD's overall FY2007 diversion rate was 60 percent (73% C&D debris diversion rate and 40% diversion rate for non-hazardous municipal solid waste).⁶

An assessment of biomass resources on or near federal installations by the Department of Energy, Biomass and Alternative Methane Fuels found that there are:

- nearly 4,700 raw wood processors within a 50 mile radius of 1,800 large federal facilities;
- nearly 1,200 federal facilities within 15 miles of a landfill and 500 landfills without an active biogas project; and
- 850 large wastewater treatment plants located within 15 miles of almost 1,400 federal facilities.⁷



Federal facilities within 15 miles of a candidate landfill.

Source: http://www1.eere.energy.gov/femp/pdfs/bamf_landfill.pdf

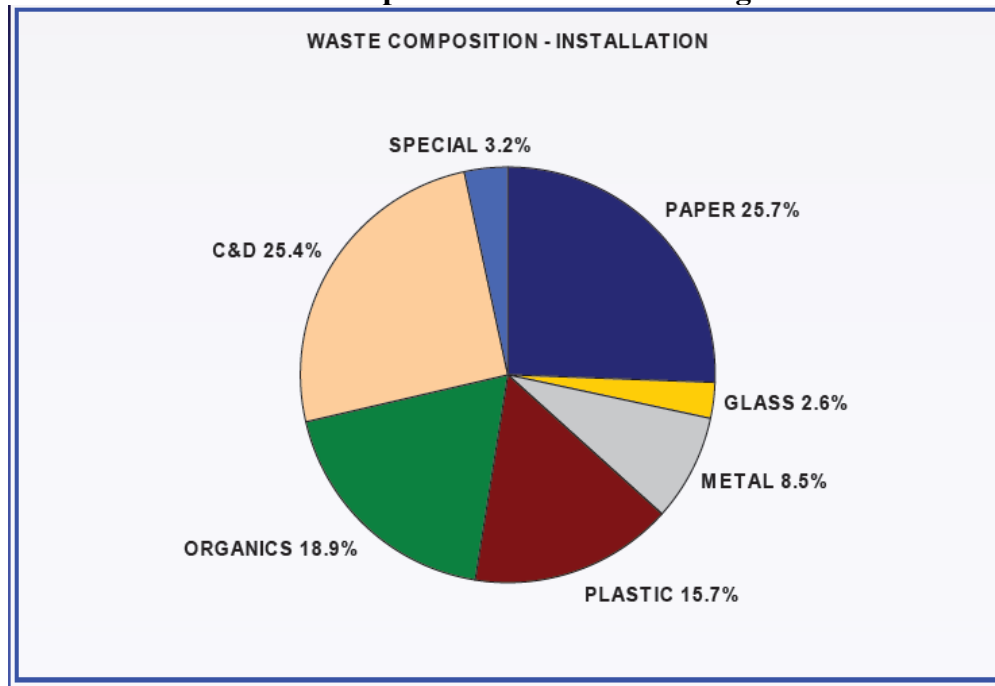
Things to Think About...

- One million tons of municipal solid waste (MSW) can yield about 300 standard cubic feet per minute (scfm) of recoverable landfill gas (LFG) or about 800 kW.
- A LFG project that uses 300 scfm yields the same reduction in green house gases as removing an estimated 6,000 cars from the road for a year.

⁶ Office of the Deputy Under Secretary of Defense Installations and Environment. Defense Environmental Programs Annual Report to Congress Fiscal Year 2007. 30 April 2008. <<https://www.denix.osd.mil/portal/page/portal/denix/environment/ARC>>.

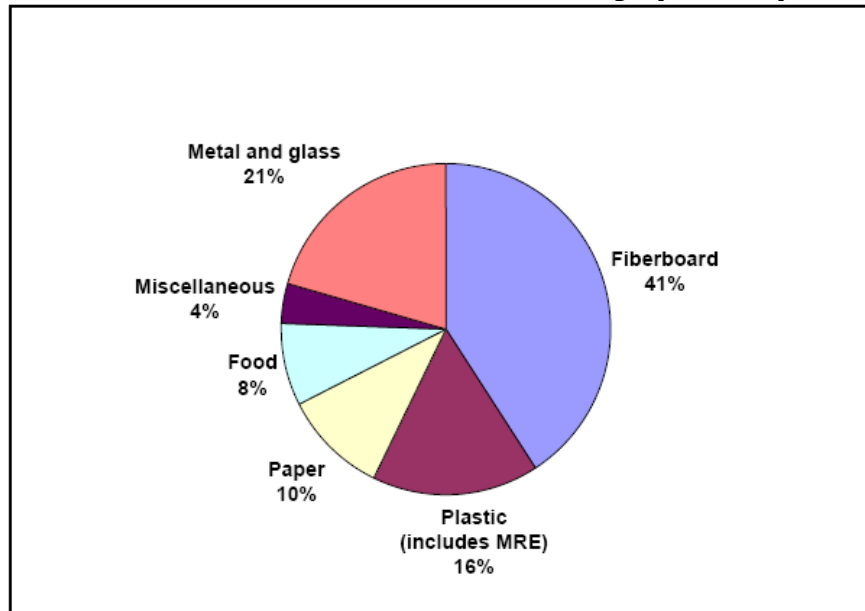
⁷ U.S. Department of Energy. Federal Energy Management Program, Biomass and Alternative Methane Fuel (BAMF) Resources Fact Sheet 30 April 30 2008. <http://www1.eere.energy.gov/femp/pdfs/bamf_resources.pdf>.

Solid Waste Composition-Aberdeen Proving Ground



Source: Solid Waste Characterization at an Army Facility, U.S. Army Center for Health Promotion and Preventative Medicine, Ground Water and Solid Waste Program, 2007

Solid Waste Stream Characterization for Deployed Army Units



Source: An Analysis of the Energy Potential of Waste in the Field, LMI, February 2004

On average a U.S. soldier produces 7.2 pounds of waste per day. In a deployed situation, this waste is usually transported off site and either burned or buried.⁸

Energy Recovery from Waste-Today

There are waste to energy projects currently underway and contributing to DoD energy objectives. In FY2007, the DoD Energy Management Report identified two installations; 1) Eielson Air Force Base and 2) Hill Air Force Base that were generating energy from waste. The Eielson Air Force Base system processed over 560 tons of paper products in the base's central heat and power plant which provided 7.820 million Btu of energy (program currently suspended because the pellet plant is inoperable). As was stated above, thermal energy doesn't count toward the EPACT 2005 renewable energy requirement but does count towards E.O. 13423 requirements.

The second installation cited in the report was Hill Air Force Base, which generated 2.1 MWh of electricity from land fill gas and has plans to expand to 3.2 MW.

The report also referenced Dyess AFB which is pursuing a 5.5MW municipal solid waste energy plant.⁹

The focus on solid waste management within the DoD has been waste diversion through integrated waste management practices such as reduce, reuse, recycle programs. This focus has led to a cost savings in FY2007 of \$180 million. It is important that the focus remain on waste minimization/diversion and seek opportunities to address the remaining waste through energy recovery. This will focus the discussion on appropriate sizing and end-use of the energy.



Source: Environmental Protection Agency

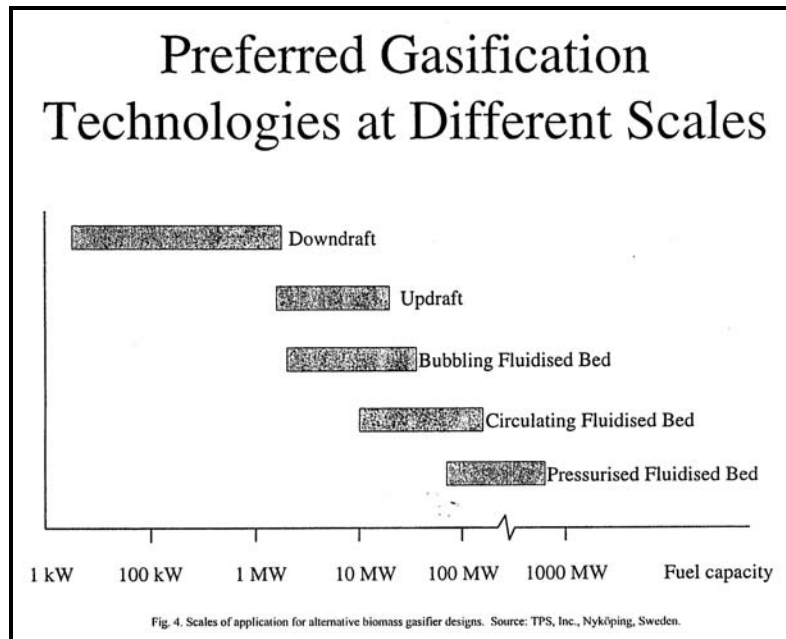
⁸ Logistics Management Institute. February 2004. "An Analysis of the Energy Potential of Waste in the Field" (DRP30T1). <<http://www.combatfeeding.org/sbir2005/files/a05-037/DRP30T1.pdf>>.

⁹ Office of the Under Secretary of Defense for Acquisition, Technology and Logistics. January 2008. Department of Defense Annual Energy Management Report. 01 May 2008. http://www.acq.osd.mil/ie/irm/Energy/energymgmt_report/fy07/DoD-Narrative-Final.pdf

SCALE- INSTALLATION and DEPLOYABLE

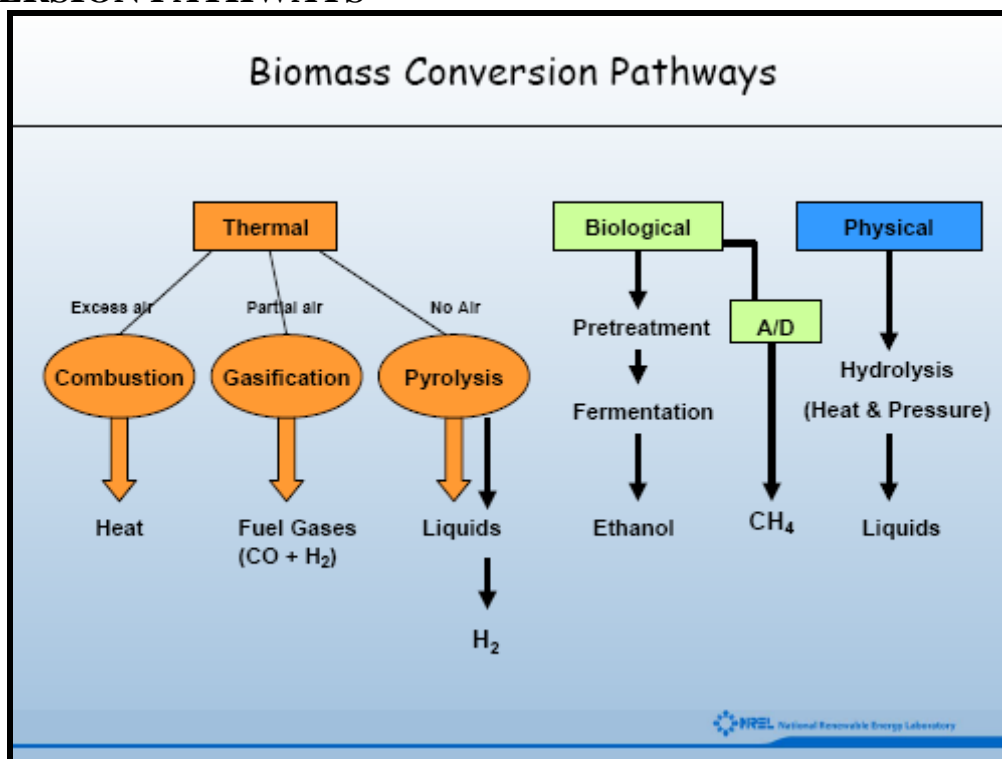
It is necessary when considering waste to energy that an evaluation be done to determine the proper scale of the system and the end use for the energy (electrical or thermal or combined heat and power). There is greater flexibility when considering a waste to energy system for an installation. Depending upon waste resource availability, quantity and energy needs, the system can be scaled within the 1 MW and up range.

However, when considering deployable systems, these systems will generally be scaled between the 60kW to 1MW range for ease of deployment, transport, set up and tear down and resource quantity. The amount of available waste will drive the scale of the system and the appropriate technology.



Source: Larson, Eric D., "Small-Scale Gasification-Based Biomass Power Generation," January 1998.

CONVERSION PATHWAYS



Source: National Renewable Energy Laboratory

As seen above, there are three types of conversion pathways that biomass/waste can undergo depending on what the end product is to be i.e. heat, power, liquid fuels or chemicals.

Thermochemical

Thermochemical conversion technologies convert biomass and its residues to fuels, chemicals, and power using gasification and pyrolysis technologies. Gasification—heating biomass with about one-third of the oxygen necessary for complete combustion—produces a mixture of carbon monoxide and hydrogen, known as **syngas**. Pyrolysis—heating biomass in the absence of oxygen—produces a liquid **pyrolysis oil**. Both syngas and pyrolysis oil can be used as fuels that are cleaner and more efficient than the solid biomass. Both can also be chemically converted to other valuable fuels and chemicals.¹⁰

Combustion

For many, the immediate reaction to waste to energy is the idea of incineration or combustion which holds a negative connotation that includes visible emissions and the release of toxic pollutants. Therefore, it is important to understand the differences between combustion and

¹⁰ National Renewable Energy Laboratory. 02 May 2008. Thermochemical Conversion Technologies-Projects. 05 May 2008. <http://www.nrel.gov/biomass/proj_thermochemical_conversion.html>.

gasification. Although, it is also important to note that the U.S. has about 89 operational MSW-fired power generation plants generating approximately 2,500 megawatts.¹¹

“Both gasification and combustion processes convert carbonaceous material to gases.

Gasification processes operate in the **absence of oxygen** or with a limited amount of oxygen, while combustion processes operate with **excess oxygen**. These two processes produce two different gas compositions.” Combustion gas is generally comprised of CO₂, H₂O, SO₂ NOX and particulates and when cleaned is primarily CO₂ and H₂O. While gasification produces a gas generally comprised of H₂, CO, H₂S, NH₃ and particulates and when cleaned consists primarily of H₂ and CO. The resulting byproducts are also quite different, byproducts of gasification are typically non-hazardous material whereas combustion byproducts are treated as hazardous waste.”¹²

“Combustion, or incineration, is a widely-accepted waste treatment option with many benefits. Combustion reduces the volume of waste that must be disposed in landfills, and can reduce the toxicity of waste. Combustion can also result in significant energy and material recovery — waste combustion can be used to generate energy, and in some cases, the ash that is generated can be recovered and beneficially-used (e.g., as landfill cover, or as aggregate in asphalt concrete). Air emissions from both municipal waste combustors and hazardous waste combustion units are regulated under the Clean Air Act (CAA). In addition, combustion ash must be managed as potentially hazardous waste under the purview of the Resource Conservation and Recovery Act (RCRA), and must meet all applicable federal and state regulations for disposal.”¹³

Gasification

Gasification is the process in which a solid fuel is converted into a gas. Production of a clean fuel gas makes a wide variety of power options available.¹⁴

There are currently **four types of gasifier** available for commercial use: 1) counter-current fixed bed, 2) co-current fixed bed, 3) fluidized bed and 4) entrained flow.

The **counter-current fixed bed ("up draft") gasifier** consists of a fixed bed of carbonaceous fuel (e.g. coal or biomass) through which the "gasification agent" (steam, oxygen and/or air)

¹¹ Environmental Protection Agency. Solid Waste Combustion/Incineration. 02 May 2008. <http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/sw_combst.htm>.

¹² Rezaian, John and Cheremisinoff, Nicholas P., Gasification Technologies-A Primer for Engineers and Scientists, Taylor & Francis Group, 2005, Boca Raton, FL. 02 May 2008. Google Books. <http://books.google.com/books?hl=en&id=GdOP5mrKT-oC&dq=Rezaian+Cheremisinoff+Gasification&printsec=frontcover&source=web&ots=-wcFnyiyi8&sig=e_eRzKxrZmApJ7YycSYPSS6OEhQ>.

¹³ Environmental Protection Agency. Solid Waste Combustion/Incineration. 02 May 2008. <http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/sw_combst.htm>.

¹⁴ U.S. Department of Energy, Energy Efficiency and Renewable Energy, Glossary of Energy Related Terms. 30 April 2008. <http://www.eere.energy.gov/consumer/information_resources/index.cfm/mytopic=60001#G>.

flows in counter-current configuration. The ash is either removed dry or as a slag. The slagging gasifiers require a higher ratio of steam and oxygen to carbon in order to reach temperatures higher than the ash fusion temperature. The nature of the gasifier means that the fuel must have high mechanical strength and must be non-caking so that it will form a permeable bed, although recent developments have reduced these restrictions to some extent. The throughput for this type of gasifier is relatively low. Thermal efficiency is high as the gas exit temperatures are relatively low. However, this means that tar and methane production is significant at typical operation temperatures, so product gas must be extensively cleaned before use or recycled to the reactor.

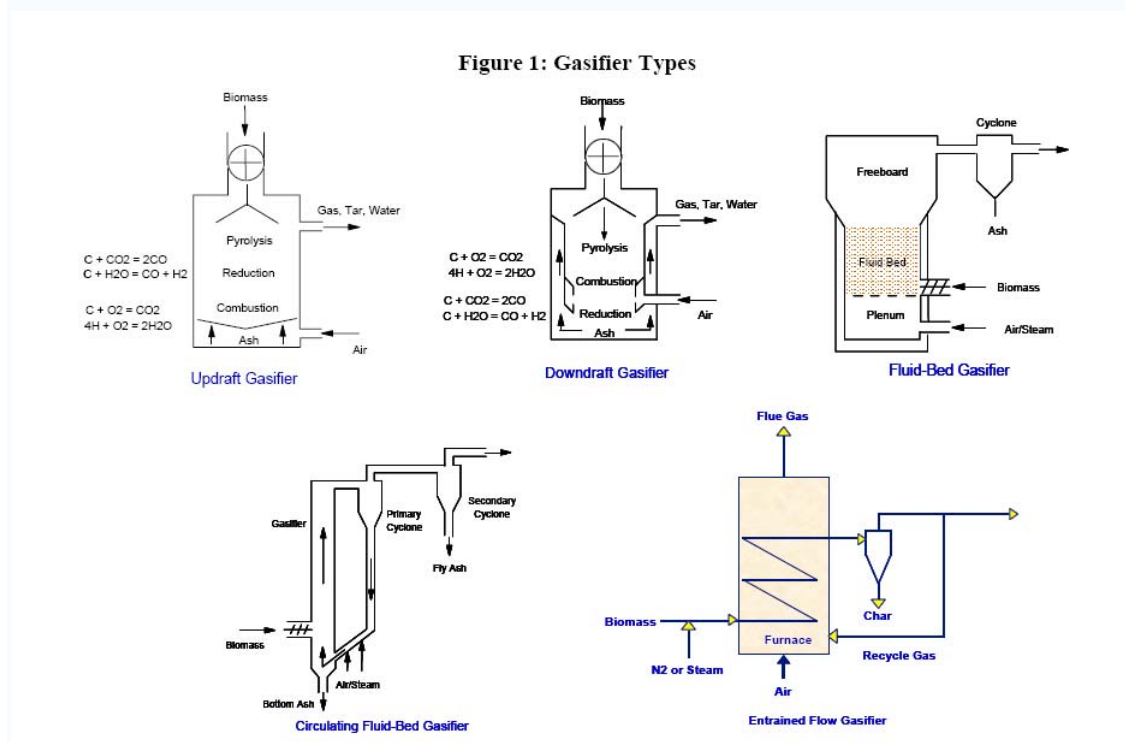
The **co-current fixed bed ("down draft") gasifier** is similar to the counter-current type, but the gasification agent gas flows in co-current configuration with the fuel (downwards, hence the name "down draft gasifier"). Heat needs to be added to the upper part of the bed, either by combusting small amounts of the fuel or from external heat sources. The produced gas leaves the gasifier at a high temperature, and most of this heat is often transferred to the gasification agent added in the top of the bed, resulting in an energy efficiency on level with the counter-current type. Since all tars must pass through a hot bed of char in this configuration, tar levels are much lower than the counter-current type.

In the **fluidized bed reactor**, the fuel is fluidized in oxygen and steam or air. The ash is removed dry or as heavy agglomerates that defluidize. The temperatures are relatively low in dry ash gasifiers, so the fuel must be highly reactive; low-grade coals are particularly suitable. The agglomerating gasifiers have slightly higher temperatures, and are suitable for higher rank coals. Fuel throughput is higher than for the fixed bed, but not as high as for the entrained flow gasifier. The conversion efficiency can be rather low due to elutriation of carbonaceous material. Recycle or subsequent combustion of solids can be used to increase conversion. Fluidized bed gasifiers are most useful for fuels that form highly corrosive ash that would damage the walls of slagging gasifiers. Biomass fuels generally contain high levels of corrosive ash.

In the **entrained flow gasifier** a dry pulverized solid, an atomized liquid fuel or a fuel slurry is gasified with oxygen (much less frequent: air) in co-current flow. The gasification reactions take place in a dense cloud of very fine particles. Most coals are suitable for this type of gasifier because of the high operating temperatures and because the coal particles are well separated from one another. The high temperatures and pressures also mean that a higher throughput can be achieved, however thermal efficiency is somewhat lower as the gas must be cooled before it can be cleaned with existing technology. The high temperatures also mean that tar and methane are not present in the product gas; however the oxygen requirement is higher than for the other types of gasifiers.

All entrained flow gasifiers remove the major part of the ash as a slag as the operating temperature is well above the ash fusion temperature. A smaller fraction of the ash is produced either as a very fine dry fly ash or as a black colored fly ash slurry. Some fuels, in particular certain types of biomasses, can form slag that is corrosive for ceramic inner walls that serve to protect the gasifier outer wall. However some entrained bed type of gasifiers do not possess a ceramic inner wall but have an inner water or steam cooled wall covered with partially solidified slag. These types of gasifiers do not suffer from corrosive slags. Some fuels have ashes with very high ash fusion temperatures. In this case mostly limestone is mixed with the fuel prior to

gasification. Addition of a little limestone will usually suffice for the lowering the fusion temperatures. The fuel particles must be much smaller than for other types of gasifiers. This means the fuel must be pulverized, which requires somewhat more energy than for the other types of gasifiers. By far the most energy consumption related to entrained bed gasification is not the milling of the fuel but the production of oxygen used for the gasification.¹⁵



Source: National Renewable Energy Laboratory

Pyrolysis

The transformation of a compound or material into one or more substances by heat alone (without oxidation). Often called destructive distillation. Pyrolysis of biomass is the thermal degradation of the material in the **absence of reacting gases**, and occurs prior to or simultaneously with gasification reactions in a gasifier. Pyrolysis products consist of gases, liquids, and char generally. The liquid fraction of pyrolyzed biomass consists of an insoluble viscous tar, and pyrolygenuous acids (acetic acid, methanol, acetone, esters, aldehydes, and furfural). The distribution of pyrolysis products varies depending on the feedstock composition, heating rate, temperature, and pressure.¹⁶

¹⁵ Wikipedia. Gasification. Wikipedia contributors. 29 April 2008. Wikipedia, The Free Encyclopedia. 02 May 2008. <<http://en.wikipedia.org/w/index.php?title=Gasification&oldid=209119869>>.

¹⁶ U.S. Department of Energy, Energy Efficiency and Renewable Energy, Glossary of Energy Related Terms. 30 April 2008. <http://www.eere.energy.gov/consumer/information_resources/index.cfm/mytopic=60001#G>.

Bioconversion

The conversion of one form of energy into another by the action of plants or microorganisms.
The conversion of biomass to ethanol, methanol, or methane.¹⁷

Fermentation

The decomposition of organic material to alcohol, methane, etc., by organisms, such as yeast or bacteria, usually in the absence of oxygen.

Anaerobic Digestion

The complex process by which organic matter is decomposed by anaerobic bacteria. The decomposition process produces a gaseous byproduct often called "biogas" primarily composed of methane, carbon dioxide, and hydrogen sulfide.

CASE STUDIES

Hill Air Force Base Landfill Gas to Energy

http://www.govenergy.com/2007/pdfs/renewable/Abbott_and_Price_Renewable_track_S8.pdf

Plant Commissioned January 2005

- First 2 years produced 13.2 million kWh
- Saved \$635K in purchased electrical cost
- Added 3rd generator increasing production to 2.1 MW (Dec 2007)
- Plan to expand to 3.2 MW

CHALLENGES WITH WASTE TO ENERGY

- Feedstock handling/pre-processing/transportation
- Feedstock (moisture content, characterization, quantity/consistency)
- Technology scale-up/down
- Producer/Syngas gas cleanup
- By-product (ash/char) handling and disposal
- Public perception
- Dispatch of electricity (siting plant near transmission lines, interconnect issues)
- Financing

¹⁷ U.S. Department of Energy, Energy Efficiency and Renewable Energy, Glossary of Energy Related Terms. 30 April 2008.
<http://www.eere.energy.gov/consumer/information_resources/index.cfm/mytopic=60001#G>.

REFERENCE LINKS

FEEDSTOCK CHARACTERIZATION

Logistics Management Institute. February 2004. **“An Analysis of the Energy Potential of Waste in the Field”** (DRP30T1). 05 May 2008. <<http://www.combatfeeding.org/sbir2005/files/a05-037/DRP30T1.pdf>>.

Ruppert, Bush, Verdonik, Geiman and Harrison, Hughes Associates, Inc. Baltimore, MD, August 2004. **“Force Provider Solid Waste Characterization Study”** (NATICK/TR-04/017) 05 May 2008. <<http://stinet.dtic.mil/cgibin/GetTRDoc?AD=ADA427565&Location=U2&doc=GetTRDoc.pdf>>

Schafstall, Tim, **“Solid Waste Characterization at an Army Facility”** Location: Aberdeen Proving Ground, MD, U.S. Army Center for Health Promotion and Preventative Medicine, Ground Water and Solid Waste Program, 05 May 2008. <http://proceedings.ndia.org/jsem2007/3813_Schafstall.pdf>.

TECHNOLOGY

Bain, Amos, Downing, Perlack **“Highlights of Biopower Technical Assessment: State of the Technology and Industry”** (NREL/TP-510-33502) April 2003. National Renewable Energy Laboratory, Technical Report. 05 May 2008. <<http://www.nrel.gov/docs/fy03osti/33502.pdf>>.

Bain, R., **“Small Modular Biopower Initiative Phase I Feasibility Studies Executive Summaries”** (NREL/TP-570-27592) February 2000. National Renewable Energy Laboratory, Technical Report. 05 May 2008. <<http://www.nrel.gov/docs/fy00osti/27592.pdf>>.

Niessen, Marks, Sommerland, Camp Dresser & McKee. **“Evaluation of Gasification and Novel Thermal Processes for the Treatment of Municipal Solid Waste”** (REL/TP-430-21612) August 1996. National Renewable Energy Laboratory. 02 May 2008. <<http://www.osti.gov/bridge/servlets/purl/10164285-7CBnFx/webviewable/10164285.PDF>>.

Timpe, Mann, Schmidt, Energy & Environmental Research Center-University of North Dakota, **“Gasification for Distributed Generation –Task 3.5 Final Topical Report”** May 1, 1999-March 31, 2000, National Energy Technology Laboratory, UND EERC-DOE. 02 May 2008. <<http://www.osti.gov/bridge/servlets/purl/824977-CdHCRS/native/824977.pdf>>.

Larson, Eric D. , **“Small-Scale Gasification-Based Biomass Power Generation”** Prepared for the Biomass Workshop, Changchun, Jilin Province China 12-13 January 1998. <http://www.princeton.edu/~energy/publications/pdf/1998/Small_scale_%20gasification.pdf>.

Rensfelt, Erik and Ostman, Anders, **“Sub-task 6-Gasification of Waste Summary and Conclusions of Twenty-Five Years of Development, IEA Biomass Agreement”** 02 May 2008. <<http://media.godashboard.com/gti/IEA/WasteIEA25years.pdf>>.

URS Corporation, Prepared for City of Los Angeles, September 2005. **“Summary Report: Evaluation of Alternative Solid Waste Processing Technologies”** <<http://www.lacity.org/SAN/alternative-technologies-summary-report.pdf>>.

URS Corporation, Prepared for City of Los Angeles, 18 August 2005. “**Conversion Technology Evaluation Report, Appendices**” 02 May 2008.

<http://www.ladpw.com/epd/tf/Attachments/SubCommittee%20Attachments/CT_Eval_Rpt_App.pdf#search=%22gasifying%20tires%20lime%22>.

POLICY

Biomass Multi-Year Program Plan March 2008, Office of the Biomass Program, Energy Efficiency and Renewable Energy, U.S. Department of Energy

<http://www1.eere.energy.gov/biomass/pdfs/biomass_program_mypp.pdf>.

<<http://www.nrel.gov/docs/fy00osti/28330.pdf>>.

U.S. Department of Energy, Federal Energy Management Program, Energy Policy Act 2005. 05 May 2008. <http://www1.eere.energy.gov/femp/about/legislation_epact_05.html>.

Executive Order 13423-Strengthening Federal Environmental, Energy, and Transportation Management. 26 January 2007. Office of the Federal Environmental Executive, Federal Register, 05 May 2008. <http://ofee.gov/eo/EO_13423.pdf> and <http://ofee.gov/eo/eo13423_main.asp>.

2007 Federal Energy Management Program (FEMP) Renewable Energy Requirement Guidance for EPACT 2005 and Executive Order 13423 Final, 28 January 2008. Prepared by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy Federal Energy Management Program. 05 May 2008. <http://www1.eere.energy.gov/femp/pdfs/epact05_fedrenewenergyguid.pdf>.

Department of Defense Key Directives

<http://army-energy.hqda.pentagon.mil/policies/key_directives.asp>.

Army Energy Campaign

<<http://army-energy.hqda.pentagon.mil/programs/plan.asp>>.

FUNDING

Energy Savings Performance Contracts (ESPC)

<<http://army-energy.hqda.pentagon.mil/policies/guidance.asp>>.

Enhanced Use Leasing (EUL)

<<http://eul.army.mil/>>.

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